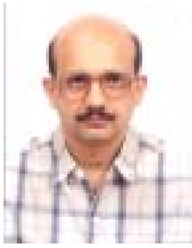
CFD APPLICATIONS TO MAVs



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Educational Qualifications:
PhD, Aerospace Engg., IISc, 1999
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Professional experience:
» Scientist in Computational & Theoretical Fluid Dynamics Division, NAL since 1988.
» Presently Scientist 'F' and Jt. Head of Division.
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Research Interests:
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» NAL Outstanding Performance Award 1994 and 1996
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ABSTRACT

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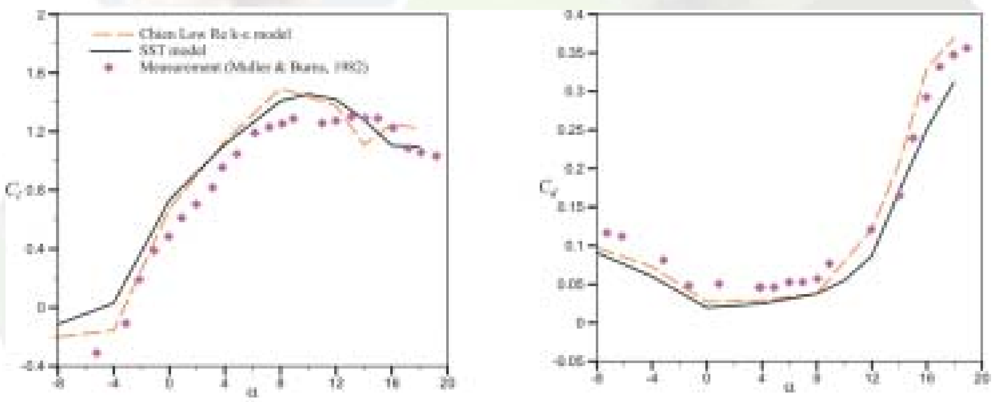
Micro Air Vehicles (MAVs) are unmanned autonomous flying machines with a linear dimension of about 15*cm*, gross take-off weight approximately 100*g* and expected loiter time of the order of about 60 minutes. The requirements of any MAV are its ability to loiter for a long duration and also to effectively maneuver in space over land, in buildings and other confined areas. Two important challenging problems in the design of MAVs are low Reynolds number aerodynamic conditions and extreme miniaturization. Aerodynamic designs of MAVs, reported in literature so far, have employed different kind of efficient lift generation system *viz.*, fixed wing[1], flapping wings[2], flexible wing[3] and rotary wings or their combinations. Fixed wings are commonly used in MAV design because they are simple and easy to implement but many researchers have observed that the fixed wing performance deteriorates when the operating Reynolds number is less than 10^5. In order to enhance the performance of the MAV, there has been great interest in the study of the aerodynamics of flapping wings and flexible wings.

In the present work, two-dimensional analysis is carried out using the in-house flow solution code RANS3D for the EPPLER-61 aerofoil configuration, for flow Reynolds number of 87,000 at different angles of attack

varying from -8^0 to $+18^0$. The RANS3D code[4, 5] developed at CTFD division NAL, Bangalore is based on an implicit finite volume algorithm to solve the time-averaged Navier-Stokes equations for unsteady incompressible turbulent flow with moving boundaries in an inertial frame of reference. This time-accurate flow solver employs a multi-block structured non-orthogonal boundary-fitted curvilinear grid with a decoupled pressure-velocity solution strategy and a variety of eddy viscosity based turbulence models. The code has been successfully parallelized using MPI libraries for efficient computation of large size problems. The RANS3D code with different turbulence models has been validated for a wide range of problems - flow past Döpler weather radome structures[6], flow around an underwater body with stern-end appendages[7], flow past aerostat balloons[8], ship hulls with a bow mounted sonar dome[9], vortex shedding behind cylinder[10,11], flow past a pitching and stationary aerofoil[12,13] *etc.*

For the present simulation a 2-block C-grid consisting of 505 ´ 100 control volumes has been employed with the far field placed at a radius of 15*c* and the minimum wall normal distance is maintained to be around 1 ´ 10^{-4} c ($y^+<1$), where *c* is the chord length of the aerofoil. The third order accurate QUICK[14] scheme for convective flux discretisation coupled to second order accurate temporal discretisation scheme with time step size $\Delta t = 0.05$ has been used for the present computations. The eddy viscosity at far field is assumed to be approximately equal to the laminar viscosity. Computations have been carried out using two turbulence models viz., $k-\varepsilon$ model of Chien[15] and Menter's SST model[16] for each of the flow situations. The figure shows the variation of lift and drag coefficients with varying angle of attack. The present computation using two different turbulence models predicts the physical trend of variation as observed in the measurement data of Muller and Burns[17]. The discrepancies observed between the present computation and the corresponding measurement data may be mainly attributed to the use of turbulence models with the assumption that the flow is fully turbulent. The performance of the low Reynolds number flow greatly depends on how accurately one can simulate the laminar to turbulent transition. Work has been initiated to incorporate the fixed transition (tripping) method in any eddy viscosity based models, e^n method, method based on intermittency factor in the RANS3D code for better simulation of the laminar-turbulent transition. The RANS3D code has recently been extended to a Large Eddy Simulation (LES) version and has been successfully tested for the flow past circular cylinder at Re=3900. LES will also be attempted for the MAV configuration to study the laminar-turbulent transition. The RANS3D code capability also needs to be extended to simulate the flapping wing aerodynamics.



Variation of lift and drag coefficients with angle of attack for Eppler-61 aerofoil at Re = *87,000*

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